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ABSTRACT

Examined were the relative effects of a number of variables, but particularly sex and field-dependence, on performance of secondary school students on Piagetian measures of formal thought. It was hypothesized that males will receive significantly higher mean scores than females on all measures; that field-independent subjects will receive significantly higher scores than field-dependent subjects on all measures; that sex, when controlled for all background variables, will not contribute significantly to mean scores on measures of formal thought; and that the factor structure among Piagetian measures of formal thought will show "written" and "manipulative" factors for females, but not for males. The main battery of measures consisted of twelve tasks, eight clinical and four written, intended to measure three Piagetian schemata: proportions, combinations and permutations, and correlations and probability. The Embedded Figures Test was administered individually as a measure of field-dependence-independence. Statistical analysis of results confirms the first two hypotheses. Rejection of the third hypothesis is discussed, and it is noted that sex and field-dependence appear to operate independently in influencing analytical problem-solving ability. As for the fourth hypothesis, no tendency was revealed for written and clinical tasks to separate into discrete factors for either males or females. (CS)

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SEX, FIELD DEPENDENCE AND FORMAL THOUGHT

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INTRODUCTION

Sex-related differences in intellectual functioning are well known, if poorly understood. Maccoby and Jacklin (1974), who have conducted the most comprehensive review available of this subject, conclude that there is a general tendency for males to perform better in mathematical and visual-spatial situations, while females often excel in the verbal mode.

There is evidence that sex differences develop during the growth of logical thought, as defined by Piaget (Inhelder and Piaget, 1958). Graybill (1975) found that the performance of males and females on four measures of formal thought was similar for nine year old subjects, but that by the age of fifteen males were significantly more successful. Reviewing a number of studies, Lawson (1975) concluded that "if it is the case that male adolescents perform more formally than females then the shift in superiority seems to come about roughly towards the end of elementary school years and during

the junior high school years." Science teachers intuitively recognize this as they see young girls becoming increasingly unsuccessful and disinterested in science, and turning away from it. Whatever its cause, the result is that science in the secondary schools and colleges, and as a profession, is dominated by men.

Another dimension in which sex differences are found is field-dependence-independence, a cognitive-style variable described by Herman Witkin. Field-dependence is usually measured by a series of perceptual tasks which Witkin feels measure abilities along a "Global-Articulated" continuum that explains broad differences in personality characteristics, including body concept and the nature of self, as well as success on non-perceptual problem-solving tasks.

The Embedded Figures Test (EFT), one measure of field-dependence, assesses the ability of a subject to find a simple figure contained in a more complex one. Witkin states that the EFT measures "the extent to which the organization of the prevailing field dominates perception of any of its parts. The person who performs in relatively field-dependent fashion follows the organization of the field as presented, whereas the relatively field-independent person is able to overcome the organization of the field, to break it up in order to

locate the sought-after component (Witkin, et. al., 1971)."

Witkin and his coauthors cite a number of experiments in which small but consistent differences were observed in the time required by males and females to complete the EFT, with males faster and more field-independent. These differences, which seem to develop after the age of 8, have been found in both western and non-western countries.

Field-dependence is also related to success on Piaget's measures of logical thought. Both Pascual-Leone and Neimark have shown that field-independent subjects achieve significantly higher scores on measures of formal thought, and Neimark was able to show a significant correlation between EFT time and performance on cognitive tasks (Neimark, 1975). Saarni (1973) demonstrated that there was a significant difference between formal operations scores for field-dependent versus field-independent females, but that this effect did not occur for males.

Finally, there is evidence that sex differences are not evenly distributed across all measures described by Piaget, and seem to occur more in the case of clinical measures requiring the manipulation of apparatus. Graybill (1975) suggested that females are more uncomfortable in this setting, and that "girls seemed particularly aware of the authority of the experimenter

and several times requested permission to perform some needed manipulation. Boys, on the other hand, appeared freer in their work." Lawson (1975) presented evidence that three written and two clinical measures of cognitive level were contained within a single factor for males, but separated into "written" and "manipulative" factors for females, and that sex differences disappeared in the case of two of three written measures.

If field-dependence is an important factor in problem-solving ability, as seems to be the case, it should be especially important in the highly manipulative clinical tasks devised by Piaget. These present a complex data array, much of it visual, with many distracting elements. Success involves the ability to see through the task, to ignore distractions, to recognize and hold separate in the mind especially salient elements of the situation that are not part of the solution to the problem. This is, of course, exactly the challenge presented by the Embedded Figures Test. Sex differences should be greatest in tasks where distracting perceptual elements are frequent, and disappear when the factor of field-dependence is controlled.

STATEMENT OF THE PROBLEM

This study represents an attempt to examine and understand the relative effects of a number of variables on performance

on Piagetian measures of formal thought. Of the background variables measured, sex and field-dependence are the most interesting, and are the bases for the following hypotheses:

1) Males will receive significantly higher mean scores than females on all measures;

2) Field-independent subjects will receive significantly higher mean scores than field-dependent subjects on all measures;

3) When controlled for all background variables, including field-dependence, sex will not contribute significantly to mean scores on measures of formal thought, and;

4) The factor structure among Piagetian measures of formal thought will show "written" and "manipulative" factors for females, but not for males.

Because the development of sex differences seems to occur near the period of adolescence, and because most studies of this sort use subjects aged 15 years or younger, the sample used in this study was chosen to extend through adolescence and into the early adult years.

DESIGN OF THE STUDY

Sample

Subjects for this study consisted of 30 males and 36 females, ranging in age from thirteen years and six months

to twenty-three years and eight months. Each subject fell into either a junior high school, high school or college group containing twenty-two individuals, of which ten were male and twelve female (table 1).

The sample was collected by eleven interviewers, each of whom contributed two subjects from each age group. The sample was largely upper middle-class, with parents' occupations ranging from farmer to bank president and education from high school to Ph.D. Each subject was interviewed for approximately one hour each week for three weeks.

Instruments

The main battery of measures consisted of twelve tasks, eight clinical and four written, intended to measure three Piagetian schemata. These were (written tasks are marked with an asterisk):

PROPORTIONS

Equilibrium on the Balance (Inhelder & Piaget, 1958)
Projection of Shadows (Inhelder & Piaget, 1958)
* Mr. Tall and Mr. Short (Karplus & Peterson, 1970)
* Recipe

COMBINATIONS AND PERMUTATIONS

Combinations of Colorless Chemicals (Inhelder & Piaget, 1958)
Combinations of Colored Tokens (Piaget & Inhelder, 1975)
Travel Between Four Cities
* License Plates
* 4-Coin Change

CORRELATIONS AND PROBABILITY

Hair Color/Eye Color (Inhelder & Piaget, 1958)
Test Bat/Standard Bat
Proportional Choice (M&M) (Piaget & Inhelder, 1975)

Interviewers were broken into three groups and trained in daily meetings over a period of three weeks (all but two were science teachers, and all had substantial prior experience with the clinical interview technique). Two sets of data were collected: the first consists of scores of either zero or one for each measure, reflecting the interviewer's judgment as to whether the task had been completed successfully; the second is based upon Piagetian protocols and allows a subject to be coded into either concrete, early formal or late formal stages. An analysis of variance across the first set of data indicates no significant interviewer effect.

An additional body of background data was collected. Socio-economic status was obtained by summing scores for father's occupation and education. The California Short Form Test of Mental Maturity was used to provide a measure of both verbal and non-verbal IQ, and digit span (both forward and backward) was included as a measure of short-term memory. The Embedded Figures Test was administered individually as a measure of field-dependence-independence. An adaptation of a four-card hypothesis testing task (Wason & Johnson-Laird, 1972) was used to identify subjects who

searched for negating evidence, and a test of the use of logical connectives, consisting of implication, disjunction and biconditional statements, was created for this study.

Statistical Procedures

Unless otherwise stated, all statistical tests were conducted with programs contained within the Statistical Package for the Social Sciences (SPSS). The first data set was used in these cases. The second set of data, in which subjects were assigned a stage-score, is used only to compare developmental patterns, and significance tested with a T-test for difference in proportions.

RESULTS

To test the hypothesis of a sex-related difference in intellectual functioning, mean scores of male and female subjects on all measures were compared by means of T-tests (table 2). Even at the relatively weak one-tailed 95% confidence interval, only four significant differences were revealed. Males were more successful on the Shadows and Mr. Tall tasks, on the total score for all proportionality tasks, and on the total Piaget score. There were no significant differences between the sexes in performance on either correlational or combinatorial tasks, or on any background variable.

A similar test was performed to compare mean scores of field-independent and field-dependent subjects (table 3). All subjects were divided at the mean EFT-time for the sample (632 seconds) and performance of the two groups compared. Among Piagetian measures, significant differences were observed for combinatorial and correlational tasks, but not those assessing proportional reasoning abilities. Field-independent subjects achieved superior scores on the chemicals, bats and M&M tasks, the total for all combinations and the total for all correlations, and the total for all Piagetian tasks.

Field-independent subjects were also significantly more successful on several background variables. They received higher scores on the logic and hypothesis-testing measures, and on non-verbal IQ.

These two comparisons yield a startling result. Although the mean time for completion of the Embedded Figures test is greater by more than 100 seconds for women than for men, this was not significant statistically. Furthermore, the differences resulting from field-dependence are found among tasks measuring schemata that are different from those resulting from sex. Analysis of covariance quickly revealed that sex differences could not be easily explained away.

There are also complications which arise from the distribution of male and female subjects around the mean for the group

for EFT-time. There are nearly equal numbers of males and females above the mean for the sample, and their mean EFT-times are virtually identical. However, below the mean most of the females are more field-dependent than any of the males. In order to arrive at a more powerful statistical procedure for looking at the third hypothesis, a series of step-multiple regression analyses were conducted (table 4).

In the first test, against combinatorial reasoning scores, only non-verbal IQ and digit span received significant regression weights (Beta). These two factors alone will explain 16.8% of the variance, and all background variables only 20%. The Betas for sex and EFT-time are not significant, and neither of these factors makes any contribution to the total score for all combinations and permutations tasks.

The next two tests show that, of the two major variables in this study, sex makes a significant contribution to total scores for proportions and EFT-time to total scores for correlations and probability. Digit span is the only other significant contributor to proportions scores, and the ability to use propositional logic is apparently important to success with correlations and probability.

A somewhat more interesting result occurs when a regression of all background variables is conducted against the total score for all Piagetian tasks. EFT-time disappears, while sex remains a significant contributor. Weak though the Beta

value for sex is, it is still more than twice as large as that for EFT-time, and the addition of EFT-time after sex does not increase the multiple correlation. Neither of the main variables in this study emerges as a major factor on the total score for all tasks. The use of propositional logic, short-term memory and non-verbal IQ are relatively more important, although Beta weights for sex and non-verbal IQ are similar. Age, socio-economic status, verbal IQ and hypothesis-testing strategy yield non-significant Betas in every regression conducted.

In order to test the hypothesis that written versus clinical formats will result in different factor structures for males and females, a procedure similar to that used by Lawson was employed. The SPSS factor analytic program was used, with a default option for eigenvalues less than one and a quartimax rotation. The Eye Color and Bats tasks were omitted, since Lawson did not use any equivalent tasks in his study.

An examination of the results reveals no tendency for written and clinical tasks to separate into discrete factors for either males or females (table 5). What is more evident is a single, very strong factor for males which contains heavy loadings for eight of the ten measures. The Shadows

and Balance tasks form a second factor, and the 4-Coin task a third. The factor structure for women is much more diverse. The first factor consists mainly of combinatorial tasks and the remainder, especially those requiring proportional reasoning, are widely scattered in the remaining three factors.

This result led to a final analysis, not suggested by the initial hypotheses. Because it was possible to derive stage-scores for all measures except the proportional choice (M&M) task, a comparison was made of the frequency of male and female subjects in each of the three age groups who received early and late formal scores. No significant differences were observed with respect to combinations and permutations, or correlations, but very interesting patterns occur in the development of proportional reasoning in the age range represented by this sample (table 6).

Using the relatively rigorous criterion of success by 75% of a sample, neither males nor females in the youngest age group are late formal on any task. Males are early formal on Mr. Tall and the Recipe, and females only on the Recipe.

In the second age group, both males and females have become early formal on all tasks. Males are also late formal on all tasks, but females only on Mr. Tall and the Recipe.

The situation is essentially the same in the third age group, with the exception that neither males nor females are late formal on Mr. Tall.

For the entire sample males are early formal on all tasks, and nearly late formal on all, not quite reaching the criterion level on the Balance and Shadows tasks. Females are early formal on all tasks but Mr. Tall, and late formal on none of the tasks. There are significant sex differences at the early formal level on Mr. Tall, and at the late formal level on all tasks except the Recipe.

Using a somewhat different criterion, the frequency of males and females in each age group who achieved success on three of four tasks, first at early formal and then at late formal level, was compared. In this analysis, there were significant differences only in the percentage of females who achieve the late formal level in the youngest age group and in the total sample.

SUMMARY AND CONCLUSIONS

The first analyses presented in this study suggest that research designed to find differences in performance on Piagetian measures as a function of sex or field-dependence-

independence will be successful. The first two hypotheses are confirmed, at least with respect to specific tasks and total score for all tasks.

The third hypothesis, that differences in performance between the sexes can be explained in terms of field-dependence and will disappear if that factor is controlled, is rejected. In fact, the situation is much more complex, and requires discussion.

Although females in this sample are more field-dependent than males, the difference is not large or significant. But more important is the observation that sex and field-dependence appear to operate quite independently in terms of their influence on analytical problem-solving ability. In particular, they seem to differentially effect different schemata in the Piagetian model of formal thought.

Field-dependence is important to the solution of correlations and probability problems, probably because the field-dependent individual is unable to array the data correctly in order to achieve a correct solution. If the problem is to evaluate a hypothesis that hair and eye color are related, confirming and disconfirming cases must be compared. In a representative task used in this study, this meant that the total number of individuals with green hair/red eyes and yellow hair/purple

eyes (confirming cases) had to be compared with the number with green hair/purple eyes and yellow hair/red eyes (disconfirming cases). Many subjects responded that they had to deal separately with two categories of hair or eye color, and that the correct answer depended upon which was chosen.

Results with respect to the proportional reasoning schema seem to arise from an entirely different source. Although males and females reach early formal levels on these tasks in the high school age range, females seem to lag behind males in the acquisition of the late formal level, resulting in sex differences in mean scores on these measures in the age range sampled. The factor analysis offers further insight into what may be taking place. Piaget's theory implies that the development of formal thought should lead to a stage in which logical thought is applied equally well across a variety of schemata. The nearly unifactor solution for the male sample, coupled with their greater success on proportionality measures, suggests that they may have approached this ideal. Females, on the other hand, do not show any degree of structuration between the schemata of combinations and proportions, and little consolidation within the proportional reasoning schema.

Lawson's result seems to derive more from the fact that his clinical and written tasks measured different schemata than that manipulative and verbal tasks are psychologically

different for females. He used a separation of variables task (Flexible Rods) and the Balance as clinical tasks. The examples he gives of his written tasks involve a "Lucky Parking Spot" measure very similar to the proportional choice (M&M) task used in this study, and a logic measure. In a factor analysis for the total sample in this study, these two types of measures loaded heavily on a correlations factor, and were unrelated either to combinations or proportions. His only other example is a combinations task, which these results suggest should load on a separate factor than the Balance for females, either in written or clinical format.

The issue of the origin of sex differences is obviously a matter of some concern to science teachers, if they wish to improve the success rates of females in their classes. Complex arguments can be constructed about sex-role stereotyping and environmental deficiencies which yield these differences, but simplistic explanations about task format or familiarity do not seem to lead far. Nor is it particularly useful to think about formal thought in some global way. Sex differences are restricted to very specific abilities, and cannot be explained away as the result of some other factor. The more important task is to find some way of mediating the difficulty females experience with proportional reasoning tasks. If this can be accomplished, their success rate in science might be expected to improve markedly.

Table 1.

Description of Sample

		AGE GROUP		
		1 (n=22)	2 (n=22)	3 (n=22)
SEX	Male	10	10	10
	Female	12	12	12
GRADE	8	1	-	-
	9	7	-	-
	10	14	-	-
	11	-	12	-
	12	-	8	-
	13	-	2	10
	14	-	-	8
	15	-	-	4

Table 2.

Comparison of Mean Scores of Male and Female Subjects on all Measures

	MALE (n=30)		FEMALE (=36)		
Background Variables	Mean	(S.D.)	Mean	(S.D.)	T-Value
EFT time (seconds)	633	(324)	754	(414)	-1.30
Hypothesis testing	.70	(.38)	.69	(.47)	.05
Logic					
Implication	4.4	(4.0)	3.1	(3.5)	1.38
Disjunction	5.3	(3.3)	5.4	(3.2)	-.06
Biconditional	4.2	(3.7)	4.5	(3.5)	-.30
IQ					
Verbal	64.9	(22.9)	61.4	(25.8)	.57
NonVerbal	64.0	(23.9)	66.1	(24.1)	-.34
Digit Span					
Forward	6.9	(1.6)	6.8	(1.3)	.26
Backward	5.3	(1.8)	5.2	(1.2)	.15
Combinations & Permutations					
Chemicals	.77	(.43)	.64	(.49)	1.12
Tokens	.90	(.31)	.92	(.28)	-.23
4-Coin	.67	(.48)	.72	(.45)	-.48
License	.70	(.47)	.64	(.49)	.52
Cities	.73	(.45)	.69	(.47)	.34
TOTAL	3.77	(1.36)	3.61	(1.27)	-.30
Proportions					
Balance	.83	(.38)	.69	(.47)	1.31
Shadows	.83	(.38)	.61	(.49)	2.02*
Mr. Tall	.87	(.35)	.67	(.48)	1.91*
Recipe	.90	(.31)	.89	(.32)	.14
TOTAL	3.43	(1.36)	2.86	(1.12)	2.07*
Correlations & Probability					
Eye Color	.73	(.45)	.64	(.49)	.81
Bats	.51	(.51)	.47	(.51)	.22
M&M	.83	(.38)	.72	(.45)	1.07
TOTAL	2.07	(.98)	1.83	(1.08)	.91
PIAGET TOTAL	9.30	(2.61)	8.42	(2.43)	2.25*

* One-Tailed P ≤ .05

Table 3.

Comparison of Mean Scores of Field Independent (FI) and Field Dependent (FD) Subjects on all Measures (Median EFT Time=632 seconds)

	FI (n=33)		FD (n=33)		
Background Variables	Mean	(S.D.)	Mean	(S.D.)	T-Value
Hypothesis Testing	.82	(.39)	.58	(.50)	2.19*
Logic					
Implication	5.1	(3.9)	2.3	(3.2)	3.18*
Disjunction	6.8	(2.7)	4.0	(3.3)	3.78*
Biconditional	5.1	(3.6)	3.7	(3.5)	1.62
IQ					
Verbal	67.9	(23.9)	58.2	(24.4)	1.64
NonVerbal	73.9	(18.0)	56.4	(25.9)	3.18*
Digit Span					
Forward	7.0	(1.2)	6.7	(1.7)	.73
Backward	5.5	(1.7)	5.2	(1.2)	.81
Combinations & Permutations					
Chemicals	.82	(.39)	.58	(.50)	2.19*
Tokens	.94	(.24)	.88	(.33)	.85
4-Coin	.73	(.45)	.67	(.48)	.53
License	.73	(.45)	.61	(.50)	1.04
Cities	.79	(.42)	.64	(.49)	1.36
TOTAL	4.00	(1.15)	3.37	(1.39)	2.03*
Proportions					
Balance	.82	(.39)	.70	(.47)	1.14
Shadows	.79	(.42)	.64	(.49)	1.36
Mr. Tall	.82	(.39)	.70	(.47)	1.14
Recipe	.88	(.33)	.91	(.29)	-.39
TOTAL	3.30	(1.05)	2.94	(1.22)	1.30
Correlations & Probability					
Eye Color	.76	(.44)	.61	(.50)	1.32
Bats	.67	(.48)	.30	(.47)	3.12*
M&M	.88	(.33)	.67	(.48)	2.09*
TOTAL	2.30	(.85)	1.58	(1.09)	3.03*
PIAGET TOTAL	9.61	(1.92)	7.88	(2.85)	2.89*

* One-Tailed P ≤ .05

Table 4.

Four Separate Step-wise Multiple Regression Analyses Against Total Scores for Three Piagetian Schemata and Total Scores on all Piagetian Measures

Dependent Variables	Independent Variables	Multiple R	Simple R	Beta
	NonVerbal IQ	.31	.31	.33**
	Digit Span	.41	.28	.30**
	SES	.42	-.10	.19
COMBINATIONS	EFT Time	.44	-.25	-.37
&	Sex	.45	-.06	-.09
PERMUTATIONS	Hypothesis Testing	.45	.12	-.07
	Verbal IQ	.45	.19	-.04
	Logic	.45	.22	.04
	Age	-	-	-
	Digit Span	.33	.33	.23**
	Sex	.41	-.25	-.22**
	NonVerbal IQ	.47	.25	.12
	SES	.49	-.33	-.14
PROPORTIONS	Verbal IQ	.49	.28	.05
	Logic	.49	.29	.07
	Age	.50	.15	.06
	EFT Time	.50	-.16	.03
	Hypothesis Testing	.50	.13	.03
	Logic	.51	.51	.43**
	EFT Time	.53	-.35	-.38*
	Verbal IQ	.54	.33	.18
CORRELATIONS	Age	.55	-.01	-.14
&	Sex	.56	-.11	-.10
PROBABILITY	SES	.56	-.21	.19
	Digit Span	.57	.19	.12
	Hypothesis Testing	.58	.22	-.13
	NonVerbal IQ	.58	.35	.08
	Logic	.44	.44	.23*
	Digit Span	.53	.37	.31**
	NonVerbal IQ	.57	.42	.25**
PIAGET	Sex	.60	-.19	-.18**
TOTAL	EFT Time	.60	-.34	-.13
	SES	.61	-.28	.11
	Hypothesis Testing	.61	-.41	-.07
	Verbal IQ	.61	.36	.08
	Age	.61	.13	-.03

* $P \leq .05$
** $P \leq .01$

Table 5.

Factor Analysis of Combinations and Proportions Tasks for Males and Females

	MALE			FEMALE			
Factor	1	2	3	1	2	3	4
* 4-Coin	-	-	.82	.41	-	.43	-
Chemicals	.52	-	.31	.72	-	-	-
Tokens	.58	-	-	.55	-	-	-
Cities	.71	-	-	.55	-	-	-
* License	.59	.28	-	-	-	-	-
Proportional Choice (M&M)	.87	-	-	.47	.32	-	-
* Mr. Tall	.72	-	-	-	.82	-	-
* Recipe	.53	-	-	-	-	-	.66
Shadows	.43	.73	-	-	.66	.32	.52
Balance	-	.96	-	-	-	.96	-

Factor loadings of less than .25 have been omitted for clarity

* Written tasks

Table 6.

Sex Differences in Frequency of Early and Late Formal Reasoning on Proportionality Tasks

a) Percentage of Subjects Successful on Individual Tasks

		Balance		Shadows		Mr. Tall		Recipe	
		M	F	M	F	M	F	M	F
Age 1	Early Formal	70	67	60	58	90	42*	90	83
	Late Formal	50	25	50	33	70	33	70	50
Age 2	Early Formal	100	83	100	83	100	75	100	92
	Late Formal	80	67	80	50	100	75	100	83
Age 3	Early Formal	80	100	90	92	80	75	90	83
	Late Formal	80	50	90	67	70	58	80	75
TOTAL	Early Formal	83	83	83	78	90	64*	93	86
	Late Formal	70	47*	73	50*	80	56*	83	69

b) Percentage of Subjects Successful on at Least Three of the Four Tasks

	Age 1		Age 2		Age 3		TOTAL	
	M	F	M	F	M	F	M	F
Early Formal	70	42	100	83	80	92	83	72
Late Formal	50	17*	90	58	80	50	73	42*

* Females significantly less successful (one-tailed $P \leq .05$, T-test for proportionality)

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